How Absorptive Capacity is Formed?

From Foreign Technology Licensing to Indigenous R&D and Innovation in Korea

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Abstract

While the literature tend to use in-house R&D as a proxy for absorption capacity and be silent about where this ability of doing R&D has come from, this paper has tried to dig out the origin of absorption capacity after defining it first as being able to conduct one's own in-house R&D and second as being thereby able to generate innovation outcomes. This paper distinguish three forms of foreign technology acquisitions based on the unique archive data from Korea, such as know-how only licensing, know-how plus patent licensing, and patent only licensing. This data show that the majority of the Korean firms started with know-how only licensing, while licensing involving patents came later. Then, an econometric analysis finds that know-how licensing associated with imported capital facility has led to firms to start their own in-house R&D, whereas licensing involving patents only tend not to be significantly related to conducting R&D, which suggests possibly substituting effect between foreign patent introduction and doing own R&D. A similar econometric exercise shows that conducting own in-house R&D as well as licensing of know-how has led the firms to be able to generate innovations or patent applications at later stages.

Key words: absorptive capacity; licensing; foreign technology; innovations; Korea; indigenous R&D;

1. Introduction

Absorptive capacity is recognized as one of the important binding constraints of economic development of the late-comers since the influential and most widely article by Cohen and Levinthal (1989). For instance, Borensztein, Gregorio, and Lee (1998) find by country panel regression that for foreign direct investment to have impact, a country should have a certain level of absorption capacity. Specifically regarding Korea as one of the most successful catching-up economies, scholars have also emphasized the importance of absorptive capacity that enabled the Korean firms to learn and assimilate such external knowledge inflow (Keller, 1996; Evenson and Westphal, 1995; Pack 1992; Dahlman 1992). However, the literature is somewhat silent about where such absorption capacity comes from. There are many empirical researches that show importance of absorption capacity by taking local R&D as its proxy but they are not providing explanation of what is required before they become able to conduct their own R&D and generate innovative outcomes (patent applications).

In the context of Korea, Korean firms started to conduct in-house R&D only from the mid 1980s but before they reach this stage, there had been a long period of learning, assimilating, and adapting foreign technology imported. Specifically, we note that the foreign technology flowed into Korea in the three form of licensing contract of know-how, patented know-how and licensing of patented technology, and that these acquisition had led to learning and formation of absorptive capacity that made firms start to conduct their own R&D activities. In other words, this paper tries to explore the 'missing link' between foreign technology (and know-how) acquisition (licensing) and the growth of indigenous R&D capability, and thereby dig the sources of formation of absorptive capacity in a late-comer economy. Such reasoning is in line with the findings by many researchers that access to external knowledge flows is especially important in such catch-up of the late-comer firms (Bell and Pavitt, 1993; Kim, 1997; Laursen and Meliciani, 2002; Park & Lee, 2006).

Cohen and Levinthal's concept of absorptive capacity is a "dynamic" in the sense it is defined as "a firm's ability to identify, assimilate, and exploit knowledge from the environment" (1989, p. 569). Although R&D spending is often used as a proxy of absorptive capacity of the firm, their notion consists of a learning process which cannot be confined to R&D (Lane, 2006). The leading firms in Korea generally begin to learn operational skills and elementary process technology before their own relevant capital investment commences. They try to master this basic technology while the production facilities are built, and test operation takes place, so that Korean engineers can take over the daily operation as soon as possible (Enos and Park, 1988; Kim, 1997). Often, foreign technologies from various sources are reorganized to fit into the latecomer's environment, and incremental improvements are incorporated into the foreign production technology. This paper is the first of its kind in applying econometric methods to the unique data of firm level foreign technology acquisitions in a developing country, to show that firms go through a process of formation of absorptive capacity long before they become able to conduct in-house R&D. Our analysis will shed a new light to the importance of this "off-the-shelf" know-how transfer since the 1970s, as it had led to formation of absorptive capacity in the process of assimilating basic operational skills and elementary operational technology, and thereby equipped firms with the ability to integrate and adapt more advanced process or design technology when they are imported later. Along this process of absorption, they become able to conduct in-house R&D, which becomes active only from the mid 1980s in Korea, and to generate their own innovations which we can measure partly by patent applications.

We have obtained a data of 3,141 foreign technology acquisition contracts, which covers all the cases concluded by non-financial listed firms in Korea from 1970 to 1993. The value and uniqueness of this data set is that the contracts are classified into three categories: the know-how-only acquisition, the know-how-and-patent-rights acquisition, and the patent-rights only acquisition. This feature enables us to examine the different outcome of the different types of foreign technology acquisition. The know-how-only typically consists of technical services and training bundled with relevant documents, corresponding to basic operational skills and elementary process technology mentioned above. The patent-rights-know-how consists of licensing of technology protected by patents that come together with technical services, training and documentations for technology, provided by the licensors. The patent-rights-only consists of patent right licensing of (mostly advanced) technology. We measure the length of learning experience of each firm by taking log of output accumulated since the year following its first acquisition of foreign know-how or patented technology.

In sum, our operational definition of absorption capacity in the first stage is being able conduct their own in-house R&D, and we will explore the link between diverse forms of foreign technology acquisition to starting their own R&D. Then, another or final verification of successful consolidation of absorptive capacity will be done by asking the question of what determines being able to innovative, and here will explore the link between doing R&D and filing patent applications. In other words, absorptive capacity is captured in two dimensions, including being able to in-house R&D and to become innovative. We apply the probit random effect model suggested by Roberts and Tybout (1997) and also adopted in Kiyota and Okazaki (2005) in the case of the Japanese firms to examine the effect of foreign technology acquisition on starting doing own R&D and generating own patent applications.

2. Foreign Technology Acquisition in Korea

We follow Mendi (2007) and Kiyota and Okazaki (2005) in using the term “foreign technology acquisition” to refer to our collection of 3,813 contracts where listed Korean firms obtained know-how and/or patent rights from abroad. Table 1 shows that throughout 1970-1975, over two thirds of foreign technology contracts consist of know-how only, and over 90% of contracts includes provision of know-how. These contracts include not only information and blue prints in printed formats, but technical services and training. Expatriate engineers usually come to Korea to make sure that initial operation in the new facilities goes as planned. Sometimes selected Korean engineers are sent abroad for overseas training.

[table 1A and 1B]

Number of foreign technology acquisition contracts concluded by listed firms experience the most drastic increase in the periods of 1976~1978 and 1982~1984, preceding large increase in the output of heavy industries, such as electric and electronic equipments, chemicals, transport equipments, and general machinery. Contracts concluded in these industries comprise over 70% of the total throughout the sample period of 1970-1993. The only exception exists for 1976-1981, when heavy investment in social overhead capital increases demand for technology in cement, and utility, i.e. electric power. However, on the average, over half of all listed firms experience foreign technology acquisition; over two-thirds for the “heavy industries” mentioned above and over 40% for the others. The ratios are very high compared to those of Japan in 1957-1970 period, where only 52% of firms in “heavy” industry, and 19% for the others participate in the foreign technology acquisitions (Kiyota and Okazaki, 2005, p.568)..

We also note that there is significant increase patent rights acquisition from 1976. According to Korea Development Bank (1991) technology bundled with patent rights tend to be of higher value than the one comprised of know-how only. This suggests that Korean firms may have been in demand for something more than mere operation of manufacturing facilities once daily production was stabilized. Adoption of patented technology may have been a means to complete absorption, assimilation, and improvement process initiated by the investment and know-how acquisition, and also a means to prevent moral hazards on the part of foreign firms when large scale capital investment did not follow (Arora, 1996). Interestingly, the number of firms acquiring patent rights becomes much smaller than those acquiring know-how in the preceding years. Over 45% of all listed firms in Korea have experience of concluding know-how only contracts, whereas the figure goes down to 37% and 6% for patent rights bundled with know-how, or patent rights only. Then, it is feasible to reason that the firms acquiring patent rights are those successful in assimilating basic operation skills and elementary process technology through know-how acquisition.

Finally, it is important to note that a significant increase in inflow of foreign technology preceded R&D efforts and innovation outcome in Korea, as shown by Figure 1. The increase in the number of foreign technology acquisition took a sharp upward trend since the mid 960, whereas increase in total R&D and Korean patent application by Korean nationals took a momentum only after the mid 1980s. It is only by mid 1980's when private R&D became the core of national R&D input. The growth rate of patent applications also follows a similar pattern, overtaking that of foreign technology acquisition in mid 1980's.

The Korean government has two objectives when they enact the provision on foreign technology acquisition in the Foreign Exchange Control Act in 1960. First, the government wants to make sure that foreign exchange, a scarce resource after the Korean War, be used only for the technology that is of critical value. Second, the government wants acquired technology to be the stepping stone on which Korean firms can build on their own technological capabilities (The Korea Development Bank, 1991). In the 1960's a Korean firm needs government approval before concluding contracts with a foreign counterpart if the firm is to receive technical assistance for a period of a year or longer and to make payment in foreign currency. The relevant ministry, namely Ministry of Commerce and Industry, scrutinizes each of such application (The Korea Development Bank, 1991).

In the 1970s Korean firms have built substantial productive and export capacities in labor-intensive light industries, such as textiles, wigs, rubber footwear, and stuffed toys but the margins in these industries are low and cash inflow insufficient to make relevant foreign debt services. Thus, both government and private sector wanted to integrate backwards into intermediate goods; if intermediate goods can be secured within the country, the need for foreign exchange should decrease in the long run. The Economic Development Plan is drawn up to support the objective. A series of legislation is enacted to promote general machinery, electronics, oil refinery and petrochemicals, transport equipment, steel, and shipbuilding industries (Byun and Park, 1989). Likewise, the approval procedure for foreign technology in the above mentioned target sectors are simplified.

By late 1970s, many of the initial entrants in the "heavy" industries acquired both physical capital and the relevant technology from foreign sources. Westphal, Kim and Dahlman (1985, pp.190-191) reports that over quarter of gross domestic investment in Korea is spent on capital goods from abroad in the 1977-1979 period. In 1978, automatic approval system was introduced for acquisition of foreign technology in sectors of general and electric machinery, shipbuilding, chemicals, textiles and finance, if: (1) the duration of the contract are 3 years or shorter; (2) the down payment is USD 30,000 or less; (3) running royalty rate is 3% or lower; and (4) fixed fee is USD 100,000 or less in total. From 1979, most sectors, other than weapons, explosives and nuclear power, are allowed for automatic approval for projects meeting certain conditions. Figure 1 and 2 show a significant increase in the number of contracts for the year 1970 and the period 1978-1980.

The deregulation process continued in the 1980's and 1990's until the filing requirement is abolished in 1994. From 1984, the approval process is simplified to the filing-and-confirmation process. From 1988, designated foreign exchange banks are entrusted to give confirmation on the foreign technology acquisition filing under certain scale (The Korea Development Bank, 1991; Korea Industrial Technology Association, 1995, p.6).

Entering new industries typically imply manufacture of products new to Korea but common in the developed world. According to Korea Development Bank (1991) survey on foreign technology acquisition of 1980's, 55% is related to technology mature in developed countries, and 70% to expansion of product mix. If we take into account the fact that 1970's are marked by government driven entrance into industries that are practically non-existent in Korea before, the numbers for the same questions are likely to be higher in the 1970's. The Korean firms find knowledge embedded in manufacturing facilities insufficient for operation and search for additional services and training, which the firms in the developed world are happy to provide them for an appropriate price; there is not much point in keeping such mature technology "secret" when the providing know-how can enable them to export large manufacturing facilities. The Japanese government's decision to move away from 'pollution-prone' 'natural-resource-consuming' heavy and chemical industries in 1971 forms a favorable environment for the Korean firms (Enos and Park, 1988).

3. Hypotheses: Building absorptive capacity through assimilation of foreign technology

Foreign technology acquisition is a process of interaction, rather than an event. Enos and Park (1988) show us that even in the most successful cases, i.e. POSCO and Hanyang Chemicals, time and efforts are necessary on the part of Korean firms before foreign technology is fully utilized. There exist three types of foreign technology acquisitions in Korea during the sample period, depending on the form of technology transferred: the know-how-only, the know-how-patent-rights, and the patent-rights-only. The know-how-only typically consists of technical services, and training bundled with relevant documents. The patent-rights-know-how consists of technical services, training and documentations, protected by patent system. The patent-rights-only consists of patent right licensing.

The know-how only

Some of the typical know-how-only included in the sample are as follows: know-how for manufacturing lubricants, cigarette filters, and epoxy resin paints; know-how for TV, radio, elevator, and escalator assembly, know-how for production of piston rings, railway brakes, boilers and pumps (Korea Industrial Technology Association, 1995). Sometimes the know-how-only contains more critical knowledge such as operation skills for naphta cracking centers, high- and low-density polyethylene and VCM (vinyl chloride monomer) production facilities, and diesel engine facilities; in general the more valuable, fundamental technology is bundled with larger scale turn-key projects.

The acquired know-how is transferred on shop floor, on person to person basis from foreign expatriates to Korean engineers, because it comes in the years when the transferee firm is newly adopting a production process, without the capability to decipher tacit contents underlying the documented sources. The primary purpose of foreign technology acquisition in this stage is to make efficient and effective investment and to reach the design operating ratio as soon as possible. Although know-how, or tacit knowledge often constitutes core competitive advantage in world leading firms (Cohen et al., 2000), the non-patented know-how transferred from a leading firm to an unrelated party in a latecomer country generally contain basic operational skills and elementary process technology, already mature and commonly known in the industrialized world. Hoekman (2005) points to the fact that leading firms transfer such technology to Korean firms in its early years of development because it is considered “off the shelf,” common and not much of value in industrialized countries’ point of view. The Korea Development Bank (1991) survey confirms that the know-how-only contracts generally contain basic operational skills and elementary process technology. Korean firms often acquire know-how-only as a part of large scale turn-key investment projects. Leading firms find it more profitable to accept such turn-key projects for a reasonable price than to refuse. Even if Gulf Oil refuses to transfer the technology for producing polyethylene plastic resins to Hanyang Chemicals, Dow Chemicals may, and there is no point in Gulf Oil to turn down the turn key project to keep the well-known tacit knowledge to itself. What matters is the price and conditions of the transfer (Enos and Park 1988, p.62). Many Japanese companies provide know-how-only’s to Korean firms in 1970’s and 1980’s after their government makes it an official policy to move towards ‘clean’ and ‘brain-intensive’ industries. It is more profitable to sell technology that is no longer necessary for themselves (Enos and Park, 1988, p.34).

Contrary to previous studies which assume that technology spill-over from imported capital goods, but in line with Von Hippel (1994), this paper acknowledges the contribution of know-how-only contracts, concluded in addition to investment contracts. The existence of well-prepared know-how-only contracts may ensure transfer of the tacit knowledge to the latecomer. Korean engineers take over the daily operation management as soon as possible, and in the process they are able to check if what they have learned is sufficient. If the knowledge is insufficient, the turn-key contractor and/or other sources including R&D specialty companies or equipment providers are contacted for additional information.

However, it is unlikely that the tacit knowledge contained in a few know-how-only contracts, imported for the purpose of capital installation and start-up, be sufficient for immediate growth of innovative capabilities or productivity. Silverberg (1991) as well as Cimoli and Dosi (1995) emphasize the fact the imitation and diffusion of technology is a part of innovation *process* which essentially leads to creativity. It should be noted that process implies certain passage in time. Even successful firms need sufficient amount of time to accumulate experience, to move from "imitation to innovation," in the words of Linsu Kim (1997).

Patent-rights plus know-how

Some of the typical patent-rights-know-how's included in the sample are as follows: know-how and patent-right licensing for production of acrylic fiber, and TPA (raw material for polyester); know-how and patent-right licensing for production of cassette player and printed circuit board; know-how and patent-right licensing for production of excavators, cranes, and automobile clutches (Korea Industrial Technology Association, 1995). About 44 percent of all foreign technology acquisition contracts of listed firms in Korea consist of patent rights bundled with know-how ("patent-rights-know-how contracts"). The ratio of this category of foreign technology contracts increases significantly after mid 1970's, when the basic manufacturing operation stabilizes for the first-movers into the "target" industries, i.e. electric and electronic equipments, chemicals, iron and steel, transportation equipments.

The patent-rights-know-how represents a stage in foreign technology acquisition where Korean firms still rely on external sources of tacit knowledge for production process upgrading, but has accumulated certain amount of shop floor experience operating newly imported foreign production facilities and have some basic knowledge on the production process. As latecomers, Korean firms are under continuous pressure to attain minimal level of productivity to survive in the international competition. Economy of scale and economy of scope are two main sources of productivity improvement for Korean firms during the sample period.

Economy of scale is a critical factor in productivity in the target industries of iron and steel, petrochemicals, general machinery, electric equipments, and transportation equipments. Economy of scope is sought as a way to generate profits without the danger of hitting the technological ceiling (Amsden, 2001, p.197). Firms invest to manufacture more of the existing products or to add novel lines of products. There comes a time when the tacit knowledge related to the product or process adopted by the latecomer is no longer as widely known in the industrialized world, and the holders of technology impose a legal binding in transferring the knowledge.

Patent-right only

Some of the typical patent-rights-only's included in the sample are as follows: patent-rights licensing for production of polycarbonate, one of the more sophisticated engineering plastic resins; patent-rights licensing for production of automobile cooling system; and patent-rights licensing for production of color TV, personal computers and PC graphics software (Korea Industrial Technology Association, 1995). As shown in Table 1, only 6 percent of foreign technology acquisitions consist of patent-rights-only ("patent-rights-only contracts"), where the latecomer is provided with only the legal rights for utilizing certain technology and not the relevant tacit knowledge.

Patent documents do not contain information sufficient for new product manufacture or new process design. Acquisitions of patent-rights-only imply that the transferee is equipped with certain level of R&D capability and do not need expatriate engineers to make detailed account on how production process is to be carried out. The latecomer is in possession of all or almost all of the necessary knowledge to adopt new production process. The R&D capability may entail the formal activities carried out in well established institutes, as well as tacit knowledge accumulated from making continuous improvements onto imported production processes.

Most of patent-rights-only's are concluded by firms in the sector of electric or electronic equipments. This can be interpreted in two ways. First, electric and electronic equipments tend to be comprised of a large number of patentable products, but Korean firms, as latecomers, are not the first to file the relevant patents, and needs licenses to produce them. Second, this is the sector in which Korean firms have been most successful in approaching the technological frontier; Koreans may not have been the first to develop the relevant technology, but they have the ability to develop, and utilize the technology without anyone providing relevant tacit knowledge.

Summary and Hypothesis

In sum, there is a sequence in the form of foreign technology acquisition in Korea. Firms begin with simple, mature technology and them move to the more complex, the advanced. Most firms, especially in the 1960's and 1970's, choose to acquire know-how that could help them construct and operate manufacturing facilities with which they are unfamiliar. The typical know-how bundle consists of technological contents in printed form as well as related training and services provided on site, by expatriate engineers. Sometimes Korean engineers are sent to the transferor's firm to learn the implementation process. Without sufficient background knowledge Korean firms find manuals and blueprints insufficient; it is critical that someone comes to show how the new technology is to work. Technology inclusive of patent rights comes later, when Koreans have better capabilities to decipher the codified content in the patents. Reliance on expatriate engineers reduces over the years, at least in the more successful cases. Improvements accumulate as firms gained experience on operation.

We find accounts of foreign technology acquisition in Enos and Park (1988) where POSCO and Hanyang Chemicals become more and more swift in learning the tacit contents of process related technology as the acquisitions are repeated. Less and less of the technology is mature, and more and more of it become patented as acquisitions are repeated, but the Korean engineers' experience in managing production facility helps them learn faster. Formal R&D activities often begin after firms accumulate certain amount of experience in assimilating foreign technology, after or sometime together with some know-how-only acquisitions.

As technological capabilities of Korean firms advanced, the in-house R&D gains importance over foreign technology acquisition because (1) foreign firms become more and more reluctant to provide core technology to potential competitors in Korea, (2) competitiveness based on labor cost disappear, and (3) government support for private R&D increases (OECD, 1996, pp.91-92). On national basis, private R&D activities become significant from 1980's but there are considerable amount of heterogeneities between firms. R&D becomes important from early 1970's in some of the leading firms.

[table 2A 2B here]

Table 2A show each case of the leading firms in Korea in terms of the dates and sequence regarding three forms of foreign technology acquisition, in-house R&D, and finally own patent applications. In the case of Samsung Electronics, it is in 1969 (the year of its establishment) that it contracted for know-how licensing, followed by know-how plus patents and patent only licensing. Then, in 1976 it first record its R&D

expenditure in its financial statement, and filed for patent applications in the year of 1978. While this seems to be a typical or majority sequence in many companies in the table and in our whole sample, there are also cases of firms taking different sequences, and the length of interval between events varies; for example, some firms took more than 5 or 10 years to start R&D after initial acquisition of foreign technology, while it happened in the same year in some other firms. We find that out of 764 firms, 385 firms (or 50.4%) have ever contracted for foreign technology, and among them in the majority cases or 233 firms (or 233/385=60.5%), know-how only was the first type of technology acquisition.

Now, table 2B show the mean and median numbers of years regarding the sequence of several events involving technology acquisitions, R&D and innovations in our sample of 764 firms. First, the average interval year between know-how acquisition and in-house R&D was 0.62 years (with 1 year as the median figure), a little bit shorter than expected, and the average year between in-house R&D and first time patent applications was 2.8 years (with 3 years as the median). Also, the average interval between know-how only and patent applications was 3.6 years with 4 year as the median. However, the table also shows that the average interval from patent-involved acquisition to R&D is negative, which means that some firms did in-house R&D first and then later contracted for patent licensing.

Now, regarding being able to generate innovative outcomes or patents, it took an average of 2.8 years after conducting R&D, and 3.6 years and 3.1 years after licensing of know-how only acquisition and know-how plus patent acquisition, respectively. From patent only acquisition to its own patent applications, it took an average of -1.2 years, which means that many firms generated their own patents before they contracted for patent licensing.

The above discussion indicates to us two things. First, the initial foreign technology acquisitions and in-house R&D activities seem to have happened with a relatively short interval or in a simultaneous manner, depending upon the types of acquisitions. This means that just conducting in-house R&D might not be a sound proof of having absorptive capacity, whereas it is just a beginning of a longer term process of building it. Second, it took roughly 3 years to generate patent applications after starting R&D or acquisition of know-how-based technologies. Thus, one might reason that being able to generate its own patents might be the final proof of having absorptive capacity or marks the end of the process of forming the capacity.

The above reasoning leads us to form a two-stage hypothesis about the origin of absorptive capacity, which states that having or not absorptive capacity can be verified by either or both of being able to conduct R&D and to generate patents.

Thus, our first hypothesis is that acquisition of foreign technology in these three forms had helped the firms learn and assimilate foreign technology and thus motivated them to start their own in-house R&D. We will test this by estimating a probit model with doing or not the R&D as the dependent variable. In other words, our first definition of absorptive capacity is being able to conduct its own R&D, and we hypothesize that those firms who acquired foreign technology by licensing were able to build up their absorption capacity, which led them toward their own R&D. In this regard, one important this is that we suspect there will be some difference among the three forms of acquisition, specifically between the modes involving know-how licensing and the mode with patent licensing only without know-how only. The reasoning is that patent licensing and in-house R&D might be substitutes each other, and thus firms licensing for foreign patents might feel less need for doing their own R&D to develop such technologies. Also, it is based on the fact that many firms conducted R&D first even before they contracted for patent licensing. Actually, as the table 2B shows, the average sequence is that patent licensing came later than in-house R&D with an interval of 3.6 years on average.

Then, the next hypothesis is about whether these firms have become able to succeed in innovations, which can be measured by patent applications. We take patent applications as a final evidence of successful consolidation of absorptive capacity. Econometrically, we hypothesize that the activities of in-house R&D is primarily responsible for being able generate patent applications, whereas we also examine the direct linkages between the three forms of acquisition to patent generations. Again, we hypothesize that while there would be a positive linkage between acquisition of know-how or know-how plus patents to patent generations, licensing of patent only would not lead to firms' own patent generations. This hypothesis is consistent with table 3B showing that while it took an average of 3 years for firm to go for patent application after they contracted for know-how only or know-how plus patent licensing, firms had already applied for their own patents on average 1.2 years before they first contracted for patent only licensing. This test is also done using a probit model with patent applications as a dummy variable.

In this exercise, one caution needs to be discussed regarding the suitability of patent applications as the evidence of being innovative. As is well-known, patents tend to reflect and express not tacit but codified knowledge. However, as verified in Jung and Lee (2010) more tacit-knowledge sectors and firms also generate patents, although not as many per unit of R&D expenditure as explicit-knowledge-oriented sectors. That is why we go for a probit estimation method with a dummy variable taking the value of one for any positive number of patent applications, rather than regular regressions with the number of patents as the dependent variable.

4. Data and Methodology

The Data and their sources

Four distinctive sets of data are combined in this paper to examine the relationship between foreign technology acquisition and firm performance in listed companies: 1) foreign technology acquisition data from 1970 to 1993, collected by Korea Industrial Technology Association (KOITA) and Ministry of Strategy and Finance (MOSF); 2) financial data from 1973 to 1996, compiled by Korea Information Service (KIS), Korea Stock Exchange, or Korea Listed Companies' Association; 3) patent application data from 1973 to 1996, provided by Korea Intellectual Property Rights Information System (KIPRIS); and 4) the list of 30 largest chaebol groups and its affiliates from 1973 to 1996, revised each year by the Hankook Ilbo (1986) or the Fair Trade Commission.

The KOITA collection presents summary of all the foreign technology acquisition contracts filed before 1994, the year compulsory filing requirements were abolished. The data set is "complete" in the sense that all firms were compelled to report conclusion of foreign technology acquisition contract where payment was to be made in foreign currency. Over half of the data consists of know-how only contracts, where tacit knowledge is the technology of interest. Know-how acquisition related to the construction of POSCO steel mills, petrochemical complexes, or Hyundai gasoline engine facilities are documented the KOITA data. KOITA collection represents larger companies that favored arm's length purchase of foreign technology to enhance their knowledge based assets, and these are the ones that have dominated technological advancement in Korea (Kim 1997, Amsden 2001).

[table 3]

As shown by Table 3, the document contains for each contract the name of the transferee and transferor, the nationality of the transferor firm, the term of the contract, the date the contract was reported to the authority, a simple description of the technological content and format, i.e. know-how, patent right, or trademark right, and the amount of royalties to be paid. There exists summary of 8,766 contracts from 1960 to 1993, and the contracts from 1970 to 1993 comprise 98% of the total, 8,587 in number. Of these, 4,175 (49%) are concluded by firms that were listed at some point between 1970 and 1996, 2,780 are concluded by non-listed-but-externally-audited firms, and 1,831 are unidentifiable. By selecting the contracts concluded 3 years ahead of the list date to the delist date, 3,813 contracts are left in the sample (44% of 8,587).

KIS provides the most extensive information on financial statements of Korean firms with information on their list and delist date. Almost all financial statements prepared by listed firms after 1980 are included in the database; however, the database is incomplete in its collection of financial statements in 1970s, and a few firms that closed business before 1986 are also missing. The financial statements provided by Korea Stock Exchange, or Korea Listed Companies' Association; are used to fill the gap.

KIPRIS provides information on all Korean patent applications filed since 1945. This paper uses 61,487 patent applications, which are identified to have been filed by listed companies between 1973 and 1996, using Korea Intellectual Property Office Database.

Information provided by Fair Trade Commission and a major newspaper company as well as the results of Lee et al. (2008) are combined to identify chaebol affiliates each year. From 1987, Fair Trade Commission has designated 30 largest conglomerates, or chaebols, and their affiliate firms each April. For 1983, 1984, and 1985 the Hankook Ilbo (1986), one of major daily newspaper company in Korea, provides report on the 50 largest chaebol groups and their affiliates.

The method of data construction

Except for the KIS database, data sources do not provide firm ID other than its name, which tend to change over time. Because names of listed firms often constitute assets of its own right, small firms are observed to use an old name of a listed firm that changed its own. This often causes confusion among researchers that uses a long panel.

This paper uses systematic method of data construction to identify each firm without errors. First, Korea Stock Exchange (1974, 1975) and Korea Listed Companies' Association (1976-1981) are compared to Jung (2008, p.7)[2] to identify the firms listed in Korea Stock Exchange at each year end, from 1974 to 1980. Second, this list is compared to KIS database; those identified with its counterpart in KIS database are given KIS firm ID number, those identified to be missing from KIS database are given an ID number distinct from the KIS ID set. Financial data, i.e. asset amount, from each database is used in the process if necessary. Third, for the companies that are listed any time between 1970 and 1996, change in firm name is traced using Korea Stock Exchange (1974, 1975), Korea Listed Companies Association (1982-1997), and each firm websites. Fourth, the listed companies are identified among licensees in KOITA foreign technology association database, as well as patent applicants of KIPRIS, and chaebol affiliates, using above mentioned history of firm names. Fifth, the four distinctive databases are combined using firm ID number and year.

According to the survey carried out by Korea Development Bank (1991, p.213) on foreign

[2] Jung (2008, p.7) presents the number of firms listed at each year end with information on firms that listed or delisted.

technology acquisition of 1980s, almost 90% of firms are able to absorb the technological contents 3 years after the conclusion of the contract. In the 1st to 3rd year of technology acquisition, 30~50% of firms still need to learn from expatriate engineers to apply the knowledge to the new environment. It is likely that application period tends to be longer when technological capabilities of the transferee is lower, i.e. Korean firms in 1970s. Therefore, it is reasonable to assume that Korean firms needed 3 years on average to before fully absorbed, assimilated and improved the foreign technology so that it could function well in the new improvement. To combine each three year into one period, this paper: 1) uses three year sum for foreign technology acquisitions and patent applications for each period; and 2) converts financial data into real KRW 3 year average applying GDP deflators to annual data.

Estimation Method and Variables

We use a probit model with random effect, using model specifications based on Bernard and Jensen (1999) and Kiyota and Okazaki (2005) to examine the effects of foreign technology acquisition and accumulated learning on formation of absorption (and innovation) capacity. Our key question is what makes firms to start doing their own in-house R&D, and thus conducting R&D is captured by a binary variable which takes the value of one at the first year a firm established in-house R&D facility. As pointed out by Nickell (1981), in a binary choice model with lagged dependent variable, parameter estimations are often biased and inconsistent. Among several strategies to handle this problem from unobserved heterogeneity, we follow Roberts and Tybout (1997) to use the probit random effect model suggested above and also adopted in Kiyota and Okazaki (2005).

The model specification is as follows:

(1) $Y_{it} = \alpha + \beta Z_{i,t-1} + \gamma Char_{i,t-1} + \delta Y_{i,t-1} + \eta_i + \mu_{it}$

where η_i is random effect and μ_{it} is pure disturbance term ($\eta_i + \mu_{it} = \varepsilon_{it}$).

- Y_{it} is a dummy variable that take the value of one if the firm conducts in-house R&D (or generates patent applications) at year t and zero otherwise in the case of R&D equation (in the case of patent equation).
- $Z_{i,t-1}$ include the key variable of our interests, such as variable representing several forms of

technology acquisition (licensing), as well as in-house R&D dummy in the case of patent application equations. Technology acquisitions are entered as one of the dummies corresponding to know-how-only, patent-rights-know-how, and patent-rights-only, respectively. We also experiment with some dummy combining two forms of acquisition against the other, as well as interactions of these forms with R&D.

- $Char_{i,t-1}$ is a vector of control (firm characteristics) variables. Firm size variable (= natural log of total assets), firm age variable (=log of firm age as of (t-1)), capital-labor ratio, industry dummies, and period dummies are used.

Further explanations about the variables are summarized in table 3. Some notes follow.

[table 4]

We use log of real asset amount as firm size dummy because it is better at representing a firm's propensity towards capital investment in absolute amount, than sales amount or number of employees, and capital investments often constitute an important part of absorbing and assimilating foreign technology. We also control for firm age, which is the number of years elapsed after establishment; firm age is observed to influence innovative outcome and productivity (Huergo and Jaumandreu, 2004a, 2004b). Capital-labor ratio indicates not only the level of past investments but also kind of technology employed by a firm just before the acquisition of foreign technology (Arrow et al., 1961). Industry dummies are given based on KSIC two-digit code. Since each period in our study consists of three-years, a three-year average is used to represent all variables, and we use a dummy variable representing each 3-year period As mentioned before, it is judgment by the bank giving out the loans for technology investment or acquirement for the Korean that it seems to take an average of three years to absorb foreign technology during the sample period (Korea Development Bank, 1991, p.213).

5. The Results: Foreign Technology Acquisition to in-house R&D

What makes firms to be able to conduct R&D

Table 5 present the results of the estimation of panel probit random effect models to find out what has made the firms being able to conduct R&D. In other words, we are interested in which types among the three types of foreign technology acquisition are directly related to formation of in-house R&D capability. Each type dummy for each of three modes is included as a regressor, separately. First in table 5A, the key explanatory variables are inserted in its one-period lagged values, together with other control variables which are lagged too. Columns of 2, 3, and 4 present the results for each type dummy, respectively. They show very clearly that the dummy for the know-how acquisition in the preceding period has a positive and significant impacts on the probability of being able to conduct R&D, whereas two other types have no significant impacts. To make sure the robustness of the results, we have created another dummy for either type2 or 3 and run regressions with this new dummy and the original dummy for know-how only. These results are shown in the first three columns of the table. The results are consistent with the separate regressions for each type; while know-how dummy is significant, patent dummy is not.

Next, in table 5B, we have tried all the current values of key variables (three types of licensing), while keeping the lagged value of other control variables. The results show that the current values of licensing for know-how only and know-how plus patents has significant and positive impact on the probably of doing in-house R&D, whereas a dummy for patent only is not significant. The results in the first column with a dummy for these first two types of licensing are consistent with the results with a separate dummy for the two types of acquisitions.

These results with lagged and current values of licensing types are consistent with the discussion in the preceding section and the table 2B that R&D and acquisition of know-how and in-house R&D proceeded with a little interval or simultaneously, whereas patent only licensing came 3 years after in-house R&D. The results also confirms the substituting relationship between in-house R&D and patent licensing.

[table 5A, 5B]

From in-house R&D to being able to generate patents

The next step is to see what makes firm to be successfully innovative, which is defined as being able to generate patent applications. Our key interests are on the effectiveness of in-house R&D activities as well as possibly different impact of three types of foreign technology acquisition. The regression results in table 6 first confirm clearly the importance of doing in-house R&D as its coefficients are positive and significant in all specifications. In other models in table 6A, we have included a dummy for the first two types (know-how only and know-how plus patents, as well as a dummy for the third type (patents only or), separately or together. Again, while the dummy involving know-how is positive significant, the dummy for patent licensing is not. These results are consistent with the information about sequencing and interval shown in table 3B, such that it took 3 or 4 years for firms licensing for know-how with or without patents to generate their own patent applications, whereas licensing for patent only came on average 1.2 years (with 3 years as median) after firms being able to generate their own patents.

Also, we find that the interactions of either the type dummy with R&D dummy are not significant. These results imply that while R&D is primarily responsible for generating patents, previous learning experience with know-how acquisition is still important as independent factor affecting innovation probability. This is interesting since the preceding results shown that those firms who licensed for know-how only acquisition are exactly those who are being able to conduct R&D. This can be interpreted as implying that learning from foreign technology tend to increase the probability of success in innovation, as in-house R&D activities do.

The above results stay on when we replace the R&D dummy with the amount of R&D expenditure in next round of regressions in table 6B. The results in table are exactly the same as the preceding table. Thus, again they confirms the importance of in-house R&D, as well as the fact that having experience with foreign know-how learning tend to increase the success probability of independent R&D effort, regardless how much money you spend on the effort.

[table 6A, 6B]

6. Summary and Concluding Remarks

While the literature tend to use in-house R&D as a proxy for absorption capacity and be silent about where this ability of doing R&D has come from, this paper has tried to dig out the origin of absorption capacity after defining it first as being able to conduct one's own in-house R&D and second as being thereby able to generate innovation outcomes. This paper distinguish three forms of foreign technology acquisitions based on the unique archive data from Korea, such as know-how only licensing, know-how plus patent licensing, and patent only licensing. This data show that the majority of the Korean firms started with know-how only licensing, while licensing involving patents came later. Then, an econometric analysis finds that know-how licensing associated with imported capital facility has led to firms to start their own in-house R&D, whereas licensing involving patent only tend not to be significantly related to conducting R&D, which suggests possibly substituting effect between foreign patent introduction and doing own R&D. A similar econometric exercise shows that conducting own in-house R&D has led the firms to be able to generate innovations or patent applications at later stages, and also that having experience with foreign know-how licensing tend to increase the success probably of innovation.

This study suggests that building absorption capacity is a dynamic process that takes certain time and effort, involves tacit knowledge (know-how) more than explicit knowledge (patents), and cannot be successful without getting access to foreign knowledge-basis. Then, for this reason, we can say that just starting in-house R&D cannot be an evidence of having such capacity. Beginning of the process may be either acquisition of foreign technology or in-house R&D, and the ‘first’ end of the process would be the time when a firm registers an evidence of its own innovations. Then, this study gives us a clue about the question of how long it takes to build absorption capacity, which is not answered by any existing studies. We find that it takes at least 3 to 4 years in the case of this sample of Korean firms when we count the period from the first year of know-how licensing to the first year of patent applications

In general, this study shows that before firms being able to do in-house R&D and innovations, they were learning process involving foreign technology, especially tacit knowledge in the form of know-how, which is the origin of the absorptive capacity. Also we have learned that building absorptive capacity is a dynamic process that takes some time. While this sounds natural, this study is the first of its kind to verify the concrete linkage between foreign technology acquisition and formation of absorptive capacity.

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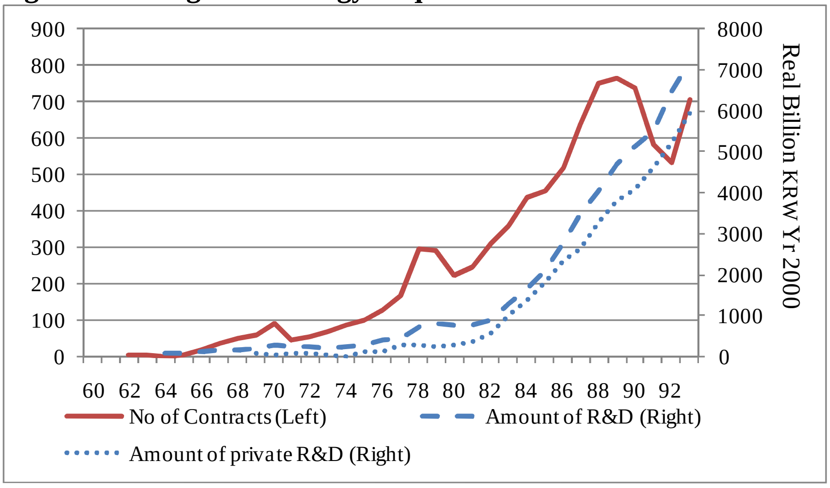
Figure 1: Foreign Technology Acquisition and R&D



Source: Korea Industrial Technology Association (1995), and National Science and Technology Information Service webpage (http://sts.ntis.go.kr)

Table 1A: Technology Acquisitions by 3 Types over 1970-93: a complete list

Year	Number of					Number of firms acquiring				Average number of technologies acquired per firm
	No of Listed firms	Technologies acquired (left)	Know-how-only acquired	Patent-rights-know-how acquired	Patent-rights-only acquired	No of firms acquiring foreign technology	Know-how-only	Patent-rights-know-how	Patent-rights-only	
1970	35	29	26	3	0	17	16	2	0	1.7
1971	36	13	10	3	0	10	8	3	0	1.3
1972	43	19	12	6	1	18	12	6	1	1.1
1973	126	15	12	3	0	13	10	3	0	1.2
1974	217	25	20	5	0	21	16	5	0	1.2
1975	292	39	16	18	5	28	14	16	5	1.4
1976	313	47	26	20	1	30	18	16	1	1.6
1977	316	37	25	12	0	23	15	11	0	1.6
1978	314	96	45	48	3	49	23	32	3	2.0
1979	303	94	44	48	2	62	37	31	2	1.5
1980	300	93	43	42	8	60	32	30	3	1.6
1981	295	96	49	36	11	70	40	32	6	1.4
1982	315	156	67	76	13	84	41	48	7	1.9
1983	344	151	79	66	6	96	62	46	4	1.6
1984	423	186	102	78	6	105	71	50	4	1.8
1985	537	196	83	98	15	105	61	55	7	1.9
1986	578	220	100	109	11	119	67	63	10	1.8
1987	605	260	132	113	13	116	85	60	10	2.2
1988	605	334	165	142	27	143	101	77	14	2.3
1989	613	356	175	164	15	131	87	72	9	2.7
1990	639	409	209	181	19	134	85	78	7	3.1
1991	644	297	153	119	23	118	78	60	10	2.5
1992	675	275	135	114	26	109	74	55	11	2.5
1993	671	370	178	163	26	113	81	60	10	3.3

Source: Tabulation using the data from Korea Industrial Technology Association (1995)

Note: These are the number of non-financial listed firms included in the sample used; for 1973~1993 period, firms scheduled for IPO within the next 3 years are included because their data are available.

Table 1B: Number of Technology Acquisition Contracts Concluded by Listed Firms

	No. of contracts concluded					Share(%)*					Number of firms**			Share of firms(%)		
Industry	1970 ~ 1975	1976 ~ 1981	1982 ~ 1987	1988 ~ 1993	1970 ~ 1993	1970 ~ 1975	1976 ~ 1981	1982 ~ 1987	1988 ~ 1993	1970 ~ 1993	With acquired technology 1970~1993	Without acquired technology 1970~1993	Total	With acquired technology/ R&D/ patent app.	Without acquired technology/ R&D/ patent app.	Total
Electric & Electronics	22	83	349	869	1,323	15.7	17.9	29.9	42.6	34.7	67	31	98	68.4	31.6	100.0
Chemicals	35	85	275	356	751	25.0	18.4	23.5	17.4	19.7	90	46	136	66.2	33.8	100.0
Transport Equipment	17	57	111	192	377	12.1	12.3	9.5	9.4	9.9	27	8	35	77.1	22.9	100.0
General Machinery	28	39	86	149	302	20.0	8.4	7.4	7.3	7.9	18	4	22	81.8	18.2	100.0
Other	38	199	348	475	1,060	27.1	43.0	29.8	23.3	27.8	206	266	472	43.6	56.4	100.0
Total	140	463	1,169	2,041	3,813	100.0	100.0	100.0	100.0	100.0	408	355	763	53.5	46.5	100.0
Knowhow Only	96	232	563	1,015	1,906	68.6	50.1	48.2	49.7	50.0	347	416	763	45.5	54.5	100.0
Knowhow + Patent Rights	38	206	540	883	1,667	27.1	44.5	46.2	43.3	43.7	281	482	763	36.8	63.2	100.0
Patent Rights Only	6	25	64	136	231	4.3	5.4	5.5	6.7	6.1	42	721	763	5.5	94.5	100.0
R&D/Sales (%)	0.08	0.14	0.24	0.82	0.74	73.6	76.3	91.3	96.0	95.3	649	114	763	85.1	14.9	100.0
No. of Patents***	49	332	6,304	46,039	52,724	59.2	76.2	96.9	99.1	98.7	316	447	763	41.4	58.6	100.0

Source: Korea Industrial Technology Association (1995), National Science and Technology Information Service webpage (http://sts.ntis.go.kr), and Korea Intellectual Property Rights Information Office webpage (http://www.kipris.or.kr/)

Note: * "Share(%)" in the row of "R&D/Sales(%)" refer to the amount of R&D carried out by firms with past experience of foreign technology acquisition over all R&D expenditure. Likewise, "Share(%)" in the row of "No. of Patents" refer to the number of patent applications filed by firms with past experience in foreign technology acquisition over all patent applications.

** "Number of Firms" in the row of "R&D/Sales(%)" or "No. of Patents" refer to number of firms that have R&D expenditure or patent application for any time between 1970 and 1993.

*** Number of patent applications.

Table 2A: From Acquisition of foreign technologies to In-house R&D and Patent applications

Cases of selected Korean firms

Name	Year of Establish-ment	Industry	1st know-how-only contract	1st patent rights+know-how contract	1st patent rights-only-contract	1st R&D	1st patent application
Samsung Electronics	1969	Electric & Electronics	1969	1975	1972	1976	1978
LG Electronics	1959	Electric & Electronics	1966	1967	1975	1976	1976
Daewoo Electronics	1971	Electric & Electronics	1968	1982	1975	1975	1982
Hynix Semiconductor	1949	Electric & Electronics	1983	1983	1986	1983	1985
Hyundai Motors	1967	Transport Equipments	1968	1977	1986	1975	1983
Kia Motors	1944	Transport Equipments	1966	1967	N/A	1975	1979
LG Semiconductor	1989	Electric & Electronics	1983	1980	1992	1989	1985
Samsung SDI	1969	Electric & Electronics	1985	1978	1983	1974	1976
POSCO	1968	Iron and Steel	1970	1971	N/A	1983	1977
Samsung Electro-Mechanics	1973	Electric & Electronics	1982	1983	N/A	1975	1982
Kolon	1957	Chemicals	1972	1980	1989	1980	1976
LG Chemicals	1947	Chemicals	1970	1971	1979	1975	1970

Table 2B: From Acquisition of foreign technologies to In-house R&D and Patent applications

Calculation of Average Intervals by Pair-wise and Sequence of the Events

From:	To:	Mean	Median	Min	Max	No. firms
know-how	R&D	0.62	1	-16	16	296
know-how +patents	R&D	-0.25	0	-14	17	240
Patents only	R&D	-3.6	-3	-17	16	39
R&D	Patents	2.8	3	-20	18	245
know-how	Patents	3.6	4	-19	22	146
know-how +patents	Patents	3.1	3	-14	19	122
Patents only	Patents	-1.2	-3	-9	13	15

		share 1	share 2
Total Sample firms	764	100.0%	
No. of firms ever acquired foreign Tech.	385	50.4%	100.0%
Those who started with know-how only licensing	233		60.5%
Thos who started with know-how + patents	135		35.1%

Sources: Authors from their data base.

Table 3: Foreign Technology Acquisition Data Sample: The image of the original data book

番號	技術導入者	技術提供者	期間 (年)	認可·申告 日字	導入技術	技術內容	代價支給	備考
27	大韓電線	마르콘電子 (日 本)	3	68.12.10	弱電콘덴사	情報및資料 技術指導	보증금: $25千 경 : 2.5%	滿了

No	Transferee	Transferor	Term (Year)	Report Date	Technological Content	Type of Technology	Payment	Note
27	Taihan Electric Wire Co., Ltd.	Marcon Electronics (Japan)	3	Dec. 10, 1968	Weak Current Condenser	Know-how (Data and Information, Technological Training)	Deposit: USD 25,000 Royalty: 2.5%	Transfer Completed

Source: Korea Industrial Technology Association (1995)

Table 4: Summary and description of Variables

Dependent Variables	
R&D dummy	= 1 if a firm conducted R&D in the current (three-year) period.
Patent dummy	= 1if a firm has applied for more than zero patents in the current period
Variables related to foreign technology acquisitions:	
know-how only dummy (Type1)	=1 if the firm acquires foreign know-how-only
know-how+patent dummy(Type2)	=1 if the firm acquires foreign know-how plus patent-rights
Patent only dummy (Type3)	=1 if the firm acquires foreign patent-rights-only
Patent dummy (Type2 or32)	= 1 if the firm acquire patents (either alone or together with know-how)
Know-how dummy (Type1 or 2)	= 1 if the firm acquire know-how (either alone or together with patents)
size of R&D expenditure	ln(R&D expenditure) t-1 , where it takes a three-year average of the amount when it is greater than 0, and it is defined as ln (0.5) if R&D expenditure t = 0.

Control Variables:	
p_age $_{t}$, : firm age	ln(firm age)$_{t}$, , based on firm age as of end of (t)
p_asset $_{t-1}$, : firm size	ln(asset amount) $_{t-1}$ is in real thousand KRW
p_CR$_{t-1}$: capital-labor ratio	ln(capital-labor ratio$_{t}$) = ln(fixed assets excluding land$_{t}$ / employee $_{t}$)
p_ind $_{t}$: industry dummy	given according to KSIC two digit-code
p_period t : period dummy	period 1: 1970~1972, period 2: 1973~1975, period 3: 1976~1978, period 4: 1979~1981, period 5: 1982~1984, period 6: 1985~1987, period 7: 1988~1990, period 8: 1991~1993, period 9: 1994~1996

Table 5: What determines the probability of getting to conduct in-house R&D : Panel Probit Random Effects

Part A: With Lagged Values	(1)	(2)	(3)	(4)
Know-how-only dummy$_{t-1}$	0.325***	0.329***		
	(3.425)	(3.524)		
Patent-rights+knowhow dummy$_{t-1}$			0.09	
			(0.849)	
Patent-rights-only dummy$_{t-1}$				-0.023
				(-0.0742)
Technology-including -patent-rights dummy$_{t-1}$	0.021			
	(0.193)			
R&D dummy$_{t-1}$	1.173***	1.173***	1.164***	1.165***
	(13.710)	(13.730)	(13.570)	(13.580)
ln(Total assets)$_{t-1}$	0.122***	0.123***	0.144***	0.151***
	(3.516)	(3.597)	(4.176)	(4.429)
Capital-labor ratio$_{t-1}$	-0.000*	-0.000*	-0.000**	-0.000**
	(-1.949)	(-1.950)	(-1.962)	(-1.973)
ln(Firm age)$_t$	0.076	0.076	0.078	0.078
	(1.006)	(1.006)	(1.021)	(1.018)
Constant	-3.415***	-3.433***	-3.356***	-3.461***
	(-5.104)	(-5.181)	(-5.023)	(-5.220)
Industry dummy$_t$	Yes	Yes	Yes	Yes
Period dummy$_t$	Yes	Yes	Yes	Yes
Observations	3,206	3,206	3,206	3,206
Number of firms	754	754	754	754
Log-likelihood	-1,174	-1,174	-1,180	-1,180
Wald chi2	867.1	867.3	860.2	859.9
prob>chi2	0.000	0.000	0.000	0.000
Lrtest(chibar2)	5.160	5.150	6.450	6.610
p(rho=0)	0.012	0.012	0.006	0.005

Part B: With Current Values	(1	(2)	(3)	(4)
Know-how-only dummy$_t$				
Patent-rights+knowhow dummy$_1$	이걸	가지고	표	만들기
Patent-rights-only dummy$_t$				
Technology-including –know-how dummy$_t$				
R&D dummy$_{t-1}$	1.173***	1.173***	1.164***	1.165***
	(13. 10)	(13.730)	(13.570)	(13.580)
ln(Total assets)$_{t-1}$	0.122***	0.123***	0.144***	0.151***
	(3.516)	(3.597)	(4.176)	(4.429)
Capital-labor ratio$_{t-1}$	-0.000*	-0.000*	-0.000**	-0.000**
	(-1.949)	(-1.950)	(-1.962)	(-1.973)
ln(Firm age)$_t$	0.076	0.076	0.078	0. 78
	(1.006)	(1.006)	(1.021)	(1.018)
Constant	-3.415***	-3.433***	-3.356***	-3.461***
	(-5.104)	(-5.181)	(-5.023)	(-5.220)
Industry dummy$_t$	Yes	Yes	Yes	Yes
Period dummy$_t$	Yes	Yes	Yes	Yes
Observations	3,206	3,206	3,206	3,206
Number of firms	754	54	54	754
Log-likelihood	-1,174	-1,174	-1,180	-1,180
Wald chi2	867.1	867.3	860.2	859.9
prob>chi2	0.000	0.000	0.000	0.000
Lrtest(chibar2)	5.160	5.150	6.450	6.610
p(rho=0)	0.012	0.012	0.006	0.005

Table 6A: What determines of the Probability of getting to have innovations : with R&D dummy

Dependent Variable	Patent application dummy$_t$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Panel Probit Random Effects						
R&D dummy$_{t-1}$	0.194**	0.189**	0.191**	0.188**	0.210**	0.193**	0.206**
	(2.140)	(2.105)	(2.121)	(2.092)	(2.148)	(2.023)	(2.068)
Know-how-only dummy$_{t-1}$		0.344***		0.337***	0.418***		0.416**
		(4.388)		(4.241)	(2.664)		(2.561)
(Know-how-only*R&D dummy)$_{t-1}$					-0.095		-0.102
					(-0.545)		(-0.557)
Technology-including -patent-rights dummy$_{t-1}$			0.108	0.049		0.116	0.031
			(1.214)	(0.541)		(0.637)	(0.161)
(Technology-including-patent-rights*R&D dummy)$_{t-1}$						-0.01	0.023
						(-0.0510)	(0.110)
Patent application dummy$_{t-1}$	0.871***	0.885***	0.873***	0.885***	0.885***	0.873***	0.884***
	(8.597)	(8.866)	(8.633)	(8.862)	(8.858)	(8.633)	(8.854)
Capital-labor ratio$_{t-1}$	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(-3.654)	(-3.700)	(-3.618)	(-3.680)	(-3.705)	(-3.618)	(-3.681)
ln(Total assets)$_{t-1}$	0.409***	0.363***	0.395***	0.358***	0.364***	0.395***	0.359***
	(8.944)	(7.961)	(8.435)	(7.716)	(7.964)	(8.435)	(7.719)
ln(Firm age)$_t$	0.064	0.064	0.067	0.065	0.063	0.067	0.065
	(0.692)	(0.701)	(0.726)	(0.716)	(0.699)	(0.726)	(0.715)
Constant	-9.646***	-8.855***	-9.383***	-8.765***	-8.881***	-9.384***	-8.789***
	(-10.07)	(-9.318)	(-9.666)	(-9.120)	(-9.319)	(-9.665)	(-9.121)
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Period dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,206	3,206	3,206	3,206	3,206	3,206	3,206
Number of firms	754	754	754	754	754	754	754
Log-likelihood	-1,285	-1,276	-1,285	-1,276	-1,276	-1,285	-1,276
Wald chi2	576.0	605.0	583.8	607.0	605.1	583.8	607.1
prob>chi2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lrtest(chibar2)	23.06	22.02	21.55	19.74	20.02	21.53	19.75
p(rho=0)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes:

1. Standard errors in parentheses

2. ***, **, and * in the cells indicate the levels of significance of 1, 5 and 10%, respectively.

Table 6B: What determines of the Probability of getting to have innovations : with R&D expenditure

Dependent Variable	Patent application dummy$_t$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
R&D expenditure$_{t-1}$	0.026***	0.025***	0.026***	0.025***	0.028***	0.025***	0.027***
	(3.388)	(3.346)	(3.354)	(3.326)	(3.321)	(3.011)	(3.129)
Know-how-only dummy$_{t-1}$		0.341***		0.335***	0.408***		0.415***
		(4.372)		(4.233)	(3.308)		(3.265)
(Know-how-only*R&D)$_{t-1}$					-0.009		-0.011
					(-0.698)		(-0.808)
Technology-including -patent-rights dummy$_{t-1}$			0.103	0.042		0.072	-0.003
			(1.158)	(0.471)		(0.502)	(-0.0203)
(Technology-including-patent-rights*R&D)$_{t-1}$						0.004	0.006
						(0.274)	(0.403)
Patent application dummy$_{t-1}$	0.878***	0.890***	0.880***	0.889***	0.892***	0.880***	0.890***
	(8.682)	(8.931)	(8.713)	(8.923)	(8.942)	(8.707)	(8.933)
Capital-labor ratio$_{t-1}$	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(-3.571)	(-3.614)	(-3.540)	(-3.598)	(-3.631)	(-3.526)	(-3.598)
ln(Total assets)$_{t-1}$	0.379***	0.335***	0.366***	0.331***	0.337***	0.366***	0.332***
	(8.232)	(7.305)	(7.794)	(7.107)	(7.332)	(7.781)	(7.126)
ln(Firm age)$_t$	0.057	0.058	0.06	0.059	0.056	0.061	0.058
	(0.629)	(0.645)	(0.663)	(0.659)	(0.627)	(0.671)	(0.650)
Constant	-8.591***	-7.861***	-8.367***	-7.792***	-7.913***	-8.353***	-7.829***
	(-9.029)	(-8.334)	(-8.707)	(-8.189)	(-8.353)	(-8.685)	(-8.198)
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Period dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,206	3,206	3,206	3,206	3,206	3,206	3,206
Number of firms	754	754	754	754	754	754	754
Log-likelihood	-1,282	-1,273	-1,281	-1,272	-1,272	-1,281	-1,272
Wald chi2	593.3	620.2	600.3	621.7	622.2	600.0	623.9
prob>chi2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lrtest(chibar2)	19.98	17.68	18.83	17.51	17.55	18.82	17.30
p(rho=0)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes:

1. Standard errors in parentheses

2. ***, **, and * in the cells indicate the levels of significance of 1, 5 and 10%, respectively.